Trends in the use of vagus nerve stimulation for epilepsy: analysis of a nationwide database

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Object. Vagus nerve stimulation (VNS) plays a significant role in the treatment of intractable epilepsy. The goal of this study was to analyze trends in the use of VNS for epilepsy in the US by using a nationwide database.

Methods. Data for patients undergoing VNS were obtained from the nationwide inpatient sample for the years 1998-2005. Trends regarding number of procedures, length of stay (LOS), hospital charges, patient sex, and payer information were retrieved and analyzed.

Results. The number of VNS procedures for epilepsy increased between 1998 and 2003 but decreased in the subsequent 2 years. The LOS and hospital charges showed yearly increases. Female patients underwent VNS implantation more than males did, and most procedures were performed in the 18- to 64-year-old age group. The combination of Medicare and Medicaid provided most of the funding for VNS from 2002 through 2005. The VNS procedures were performed mostly in teaching hospitals.

Conclusions. Trends from a national database reveal consistent use of VNS for intractable epilepsy. Greater use of the procedure appears to be reflected in the female population, and the procedure has been performed most often at tertiary care teaching hospitals, where a comprehensive evaluation for all forms of therapy is arguably best able to target appropriate patients for appropriate therapies. With the recent application of VNS to target populations without epilepsy, such as patients with refractory depression, the trend of continued use of this treatment for epilepsy appears likely. (DOI: 10.3171/FOC/2008/25/9/E10)

KEY WORDS • epilepsy surgery • intractable epilepsy • seizure disorder • vagus nerve stimulation

Approximately 0.5–1% of the population is estimated to have epilepsy, although as many as 25–50% of patients either lack adequate seizure control or experience unacceptable side effects.6,14 The vagus nerve stimulator was the first device approved for refractory partial-onset seizures in adults and adolescents at least 12 years of age on July 16, 1997, following 2 multicenter, randomized, parallel, active-control trials (EO3 and EO5) that demonstrated its safety and efficacy.5,15

Although the precise mechanism remains uncertain, stimulation of the left cervical vagus nerve has confirmed the influence of VNS on multiregional cerebral and brainstem neuronal networks.3,15

Despite the surge in the number of new antiepileptic drugs, the greater availability of resective epilepsy surgery, and the resurfacing of the ketogenic diet, in addition to other forms of investigational neurostimulation, the use of VNS has a greater relative cumulative exposure. To the best of our knowledge, this is the first study to analyze trends for VNS use in the US by using a nationwide database.

Abbreviations used in this paper: LOS = length of stay; NIS = Nationwide Inpatient Sample; VNS = vagus nerve stimulation.

Methods

Clinical data were derived from the NIS for the years 1998-2005. The NIS is maintained by the Agency for Healthcare Research and Quality, and represents a 20% random stratified sample of all patients discharged from nonfederal hospitals within the US.2 Patients who underwent VNS implantation for epilepsy were identified by the International Classification of Disease, Ninth Revision, Clinical Modification procedure code 04.92.

Data were extracted using the NIS from the Healthcare Cost and Utilization Project website (HCUPnet.ahrq.gov) for the total number of discharges, LOS, hospital charges (mean US$), patient sex, teaching versus nonteaching hospital, and payer information.

A two-tailed test of proportions with an alpha value of 0.05 was used to compare groups for each variable. This was performed on sex, payer, and hospital type. A probability value less than 0.025 was considered significant.
The year 2003 showed the largest number (2117), with a slight decrease in the ensuing 2 years (Fig. 1). Data were available for LOS and charges. Whereas there was a minimal increase in the LOS, the increase in charges was substantial ($20,419 in 1998 to $50,956 in 2005; Fig. 2). Most of the funding was provided by private insurance before 2002, but the combination of Medicare and Medicaid shared a larger portion of funding post-2002 (p < 0.025; Fig. 3).

In 2005, 75% of the procedures were performed in teaching hospitals, compared with > 90% in 1998. Available data on patient sex demonstrated a slow but consistent increase in the number of VNS procedures performed in females (p < 0.025; Fig. 4). Age analysis showed that the majority of patients undergoing VNS were between 18 and 64 years of age, with the > 64 age group representing < 11% of total procedures performed.

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**Table 1**

<table>
<thead>
<tr>
<th>Data compiled from the NIS on VNS procedures for the years 1998–2005</th>
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<tr>
<td>Trend in VNS Placement for Epilepsy Excluding Rounds</td>
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<tr>
<td>no. of procedures</td>
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<tr>
<td>LOS (days)</td>
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<tr>
<td>hospital charges (US$)</td>
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<tr>
<td>age in yrs (%)</td>
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<td>18–44</td>
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<td>female</td>
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<td>payer (%)</td>
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<td>Medicare</td>
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<td>combined federal</td>
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<td>private</td>
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| * Denotes unreported data.

To the best of our knowledge, this is the first analysis of the trends in VNS use in the US. The first observation is that the number of procedures performed reached a peak in 2003 and then decreased in the subsequent 2 years. This is despite evidence that the incidence of intractable epilepsy has been stable. There is no clear explanation for the trend toward a decreasing incidence of the procedure. It is possible that it simply reflects the initial enthusiasm for the first Food and Drug Administration–approved standard of care treatment for epilepsy in which a device was used. Over time however, the reduction in seizure frequency afforded by VNS may not seem as exciting to physicians. Although reimbursement to the neurosurgeon has not declined, there could have been a corporate shift of marketing toward other indications for VNS, in particular for depression.

The number of female patients undergoing VNS procedures has been significantly higher than males since 2001. The reason behind this trend is unclear, given that there is no evidence of predilection for either sex in intractable epilepsy. It is conceivable that neurologists are less likely to

**Fig. 1.** Trend graph of VNS procedures performed from 1998–2005 demonstrating a halt in the increasing trend after 2003.

**Fig. 2.** Trend graph of VNS hospital charges demonstrating a steady increase during the time period analyzed.
recommend antiepileptic drugs in women due to concerns over childbearing, and thus are more prone to resort to a non-drug treatment.

The majority of patients undergoing VNS implantation were in the 18- to 64-year age group. In fact, < 11% of patients were > 65 years of age. This is interesting because even more invasive procedures, like resection, are common and safe in the elderly.\(^1\) If seizures are clearcut and medically intractable, then VNS should be considered as a good option in older patients.

Since 2002, the combination of the 2 federal programs (Medicaid and Medicare) has provided most of the funding for VNS in the US. The difference between the federal programs and private insurance was statistically significant post-2003. In addition, hospital charges for VNS have increased dramatically during the years analyzed. Hospital- and manufacturer-based data will need to be examined to determine the cause of this pattern. Greater predisposition to federal third-party-payer support may reflect improvements in availability, coding, and reimbursement rates, as well as health care utilization over time.\(^10\)

The vast majority of VNS procedures continue to be performed in teaching hospitals. This is not surprising given that comprehensive epilepsy centers are more common in tertiary, teaching institutions. The VNS procedure is only one of the treatment strategies for refractory epilepsy, and should really be offered only by Level IV comprehensive epilepsy centers that also offer resective surgery. When resection is a good option (for example, in clear temporal lobe epilepsy or extratemporal lesional epilepsy), it should be preferred, because unlike VNS it has a higher likelihood of making patients seizure free. The VNS procedure is a good option after failed resections, in patients with true bitemporal epilepsy, in patients with symptomatic generalized epilepsy of the Lennox–Gastaut type (with multiple foci), and in the occasional patient with truly refractory idiopathic generalized epilepsy.\(^7\)

It is critical to remember that 20–30% of patients with refractory seizures do not have seizures and have been misdiagnosed.\(^8\) For those reasons, and as we have pointed out elsewhere,\(^9\) a general consensus is that VNS should always be preceded by prolonged video-electroencephalography monitoring as part of the evaluation in a comprehensive epilepsy center.

The NIS database has been widely used by neurosurgeons to analyze trends and outcome.\(^4,11-13,17\) Nonetheless, it represents only a 20% random, stratified sample of all patient discharges from nonfederal hospitals within the US. Although absolute conclusions are difficult to make from these data, it is reasonable to analyze the relative trends over time. Our study has other limitations; inaccurate coding of diagnoses and procedures could lead to over- or underestimates of the trends presented in the NIS database. This issue has been raised before.\(^10\) When it comes to unique procedures, such as implantation of a VNS device, the coding is probably more accurate and consistent. One exception, however, is that there is only one code for both implantation and removal or revision of stimulator. Another limitation is that the data originate from a selected number of US hospitals, which may introduce bias in patient selection.

Conclusions

Trends from a national database reveal consistent use of VNS for intractable epilepsy since the initial Food and Drug Administration approval, continuing through 2005. Greater use of the procedure appears to be reflected in the female population, and remains an option for long-term therapy for patients with refractory epilepsy due to a uniquely favorable adverse event profile. The VNS procedure remains a “surgery” used for treatment of epilepsy and has been performed most often at tertiary care teaching hospitals, where a comprehensive evaluation of all forms of therapy is arguably best able to target appropriate patients for appropriate therapies. With the recent application of VNS to target populations without epilepsy, such as patients with refractory depression, the trend of continued use of VNS in the future appears likely.

Disclaimer

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Acknowledgment

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References

2. Agency for Health Care Research and Quality: Nationwide In-

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**Fig. 3.** Bar graph of payer distribution demonstrating the increase in funding for VNS by federal programs (Medicare and Medicaid) between 1999 and 2005.

**Fig. 4.** Bar graph of VNS procedures and gender distribution between 1999 and 2005 demonstrating a higher number of procedures performed in females.

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